RESEARCH ARTICLE

Helping children's development of inquiry skills

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Keywords:
Inquiry;
pedagogy;
skills;
understanding;
explaining

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Abstract

This paper, based partly on a key-note presentation at the Pri-Sci-Net conference in September 2013, discusses how teachers can help children develop their understanding of scientific aspects of the world around through inquiry. It begins by setting inquiry in the context of other pedagogical approaches which contribute to learning with understanding. It shows how constructivism, formative assessment and inquiry have some characteristics in common but also each make unique contributions to children's learning in science. It warns against over-simplifying inquiry by equating it only with 'practical work' or 'hands-on' activities or meaning that children have to 'discover' everything for themselves. A model of developing understanding through inquiry is presented and used to show the importance of inquiry skills in this process. This is followed by suggestions of the actions that teachers can take and examples of teachers' questions to promote progression in developing these skills.

1. Introduction

Teachers now have easy access to a wide range of activities set out in well designed programmes in print and on-line. Finding appropriate activities is not the main problem in helping children to develop scientific understanding, skills and attitudes. An activity could be carried out by some children just following instructions as in a recipe, and by other children thinking their way through from step to step. The difference is created by what the teacher does in preparation for, and during, the activity. Keeping children busy, physically active, is not the criterion for effective science teaching. Activity must be a vehicle for experience and thought, and thought is promoted by communication and discussion. The teacher's role in this process is crucial to children's learning.

This paper considers how teachers can help children to develop their understanding of the scientific aspects of the world around through inquiry-based activities. Inquiry-based education is firmly rooted in what we know about learning (Bransford et al., 1999; Gopnik et al., 1999), for example that

- children are forming ideas about the world around them from birth and will use their own ideas in making sense of new events and phenomena they encounter;
- direct physical action on objects is important for early learning, gradually giving way to reasoning, first about real events and objects and then later about abstractions;
- children learn best through mental and physical activity, when they work things out through their own thinking in interaction with adults or other children, rather than receiving instruction and information to memorise;
- language, particularly discussion and interaction with others, has an important part in the development of reasoning skills and ideas.

But inquiry-based teaching is not the only pedagogical approach that is consistent with how children learn, so we begin, in section 2, by putting inquiry in the context of other effective pedagogical approaches, before considering in more depth, in section 3, how inquiry leads to understanding and the role of inquiry skills in the process. Section 4 offers some specific suggestions for teachers in helping children to develop inquiry skills, leading to conclusions in section 5.

2. Inquiry and other pedagogical approaches

Throughout the 60 or so years of developing science in the primary school, there has been no shortage of suggestions for teaching approaches, under labels such as 'discovery', 'problem solving', 'process approach', 'learning by doing'. Some features of these have been preserved in the approaches that have been at the focus of attention in recent years; in particular:

- Constructivism
- Formative assessment
- Inquiry-based learning

These pedagogical approaches are not unique to science education; although they do have particular application in science they have relevance to learning in many subject domains. Neither are they new – they have roots in thinking and research in education which go back many years. As we will see in discussing them, they overlap in several respects, but each has a particular contribution to make to 'effective practice' in science education. So, although inquiry has captured a great deal of attention, it is important to consider it in the context of the other influences on science education pedagogy. We now briefly review the meaning of each one and then consider how they relate to each other.

2.1 Constructivism

Constructivism, inspired by the work of Jean Piaget, derives from research into the ideas of young children, which showed that children work things out for themselves from an early age and often arrive at ideas that conflict with scientific ones. These ideas – that children have worked out for themselves and believe – are not to be stamped out by telling the children the 'right' answer, which would, in many cases, be too complex for them to understand. Instead, constructivist pedagogy starts from these ideas and sees the role of the teacher as providing children with experiences and evidence and help in using reasoning skills that will enable them to construct more scientific ideas. Constructivism, based on a view of learning as being constructed by learners, has implications beyond merely revealing children's existing ideas. It involves the active participation of learners in developing scientific understanding, distinguishing it from a view of learning as the acquisition of more knowledge and skills through rote learning.

In recent thinking about learning there has been a perceptible shift away from the view that ideas are formed by individuals in isolation – that is, 'individual constructivism' – towards a view that understanding is developed through 'making sense of new experience with others' rather than by working individually. This is described as 'socio-cultural constructivism', which recognises the impact of others' ideas on the way learners make sense of things (Bransford et al., 1999). Physical objects and language also have important roles, as learners express their ideas through action and words and are influenced by the actions and words of others.

Dialogue and argumentation have been identified (Alexander, 2008; Eccles & Taylor, 2011) as particular types of talk among learners or between learners and teacher which have central roles in socio-cultural constructivism. In this context dialogue refers to conversation in which the contributions of participants are equally valued irrespective of their relative status. Exchanges of this kind encourage reflection and allow the expression of sometimes half-formed ideas which may need to be reformulated and clarified in order to be communicated to others. In argumentation, the focus is on supporting claims and conclusions with evidence. It differs from argument in everyday life and contributes to learning as suggested by Michaels et al. (2008):

> In science, goals of argumentation are to promote as much understanding of a situation as possible and to persuade colleagues of the validity of a specific idea. Rather than trying to win an argument, as people often do in non-science contexts, scientific argumentation is ideally about sharing, processing and learning about ideas. (p. 89)

2.2 Formative assessment

Formative assessment – a short-hand term for 'using assessment formatively to help learning' – involves monitoring children's ideas in relation to lesson goals and the use of this information to decide next steps in progress towards these goals. The formative use of assessment is a cyclic process in which information about children's ideas and skills informs on-going teaching. Information collected is fed back into teaching, which can be adjusted to ensure children's engagement, and fed back to children to help them overcome difficulties or move forward (Harlen, 2012, 2013).

In formative assessment teacher and children have roles in collecting and using evidence of learning as it takes place. The children's role requires that they know the goals of their work and the quality criteria to be applied so that they can themselves assess where they are in relation to the goals. This puts children in a position to identify, with their teachers, the next steps in their learning and to take some responsibility for progress towards the goals. The role of teachers in using assessment in this way is not only to find out where children are in this progress, and to provide activities with the right amount of challenge to advance their existing ideas and skills, but to share the goals with children and help them assess their own progress towards them.

2.3. Inquiry-based learning

Inquiry is a term widely used in everyday life as well as in education and other professional activities. It is sometimes equated with research, investigation, or 'search for truth'. Within education, inquiry can be applied in most subject domains – including history, geography, the arts, science, mathematics and technology – when questions are raised, evidence is gathered and possible explanations are considered. Inquiry is not a new concept in education. It has roots in the studies of Piaget (1929) and the insights of Dewey (1933) and Vygotsky (1978), among others, which revealed the important role in their learning of children's curiosity, imagination and their urge to interact and inquire.

What characterises inquiry in education is that children are taking an active part in developing their understanding and learning strategies by pursuing questions or addressing problems that engage their attention and thinking. They collect evidence and use it in making sense of different aspects of the world around. As well as building understanding, they are developing competences such as critical thinking, communication skills and ability to learn both independently and collaboratively (Duschl et al., 2007). The skills used and developed in inquiry are those used by scientists in seeking to understand the natural and made world around, and so have a similar role in children's endeavour to make sense of the scientific aspects of their environment. For this reason inquiry has captured a great deal of attention in science education and is discussed in more detail in section 3. As the same time, inquiry pedagogy has been exposed to a variety of interpretations which need to be countered. Some interpretations result from over-simplification, others from equating inquiry with existing practices which fall short of matching intentions, and others from misunderstandings of what is involved in the inquiry process in science and mathematics.

The first of these unfortunate interpretations is equating inquiry in science with 'hands-on' activities or 'practical work': this is far too limited a view. A key characteristic of inquiry is mental activity using evidence and this may be found in a range of ways beyond direct action on objects, and may come from secondary sources, the media and the internet. A related mistaken view is that inquiry means that children have to 'discover' everything for themselves and should not be given information by the teacher or use other sources. This assumes that children come to new experiences with open minds and develop their ideas by inductive reasoning about what they observe and find through their inquiries. As noted in section 2.1, children come to new experiences not with empty minds, but with ideas already formed, from earlier thinking and experiences, which they use to try to understand the new events or phenomenon. If there is no evidence to support their idea then they need access to alternative ideas to try, which may be suggested by other children, the teacher or other sources.

2.4 Overlapping approaches with some unique features

Some overlap among constructivism, formative assessment, and inquiry-based learning is clearly seen in these brief descriptions and in the summary of their main features in Box 1. However, each also has unique features to keep in mind as we now turn to focus attention in the rest of this discussion on inquiry-based learning.

Box 1: Summary of key points about pedagogical approaches

Constructivism: reflects a view of learning as a social and collaborative activity in which children develop their thinking through interaction with objects and other people.

Key points:

- Learning through mental and physical activity.
- Using existing ideas to try to understand new experiences.
- Understanding is constructed through social interaction involving dialogue and argumentation.

Formative assessment: monitoring progress towards learning goals to provide feedback to teachers and children.

Key points:

- Feedback to children in used to help them understand what is needed to for their next steps in learning.
- Feedback into teaching is used to regulate and the pace and challenge of teaching to ensure optimum opportunities for learning.
- Children are involved is assessing the quality of their work and deciding how to improve it.

Inquiry-based learning: learners progressively developing scientific ideas about the world through the use of skills of scientific investigation.

Key points:

- Children develop their understanding through collecting and using evidence at first hand and from secondary sources.
- They use the skills of investigation used by scientists..
- They report and reflect on what and how they have learned.

3. Developing understanding through inquiry

3.1 A model of learning through inquiry

The process of trying to make sense of a phenomenon, or answer a question, about why something behaves in a certain way or takes the form it does, begins in the same way for all learners – children, adults and scientists. Initial exploration reveals features that recall previous ideas leading to possible explanations ('I think it might be...' 'I've seen something like this when...' 'It's a bit like...'). There might be several ideas from previous experience that could be relevant and through discussion one of these is chosen as giving the possible explanation (hypothesis) to be tried, as represented in Figure 1.

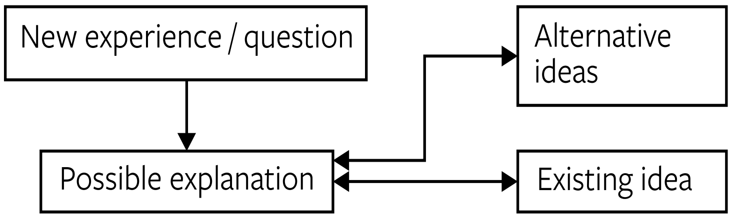

Figure 1: Linking an existing idea to give a possible explanation of a new experience

Working scientifically, learners then proceed to see how useful the chosen existing idea is by making a prediction based on the hypothesis, because only if ideas have predictive power are they valid (Hawking, 1988). To test the prediction new data about the phenomenon or problem are gathered, then analysed and the outcome used as evidence to compare with the predicted result. This is the 'prediction → plan and conduct investigation → interpret data' sequence in Figure 2. More than one prediction and test is desirable and so this sequence may be repeated several times.

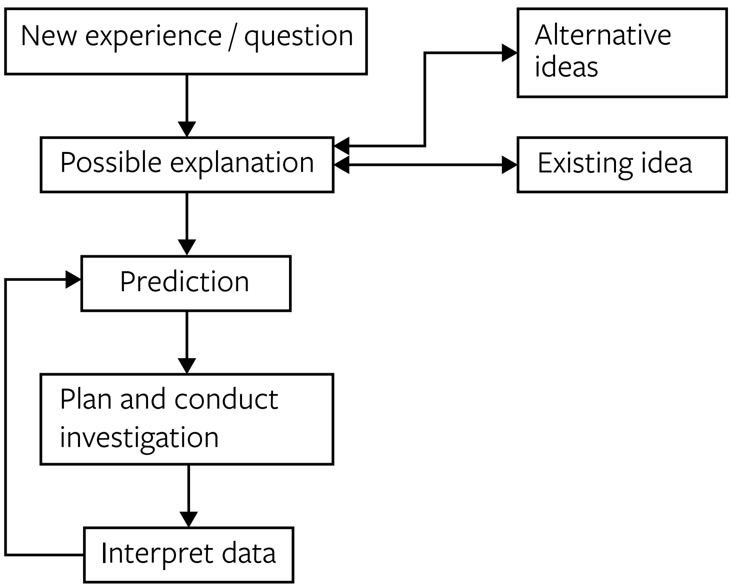

Figure 2: Testing the possible explanation

From the investigation results a tentative conclusion about the usefulness of the initial idea can be drawn and compared with the possible explanation. If it gives a good explanation then the existing idea is not only confirmed, but becomes more powerful –'bigger'– because it then explains a wider range of phenomena. Even if it doesn't 'work' and an alternative idea has to be tried (one of the alternative ideas in Figure 3), the experience has helped to refine the idea, so knowing that the existing idea does not fit is also useful.

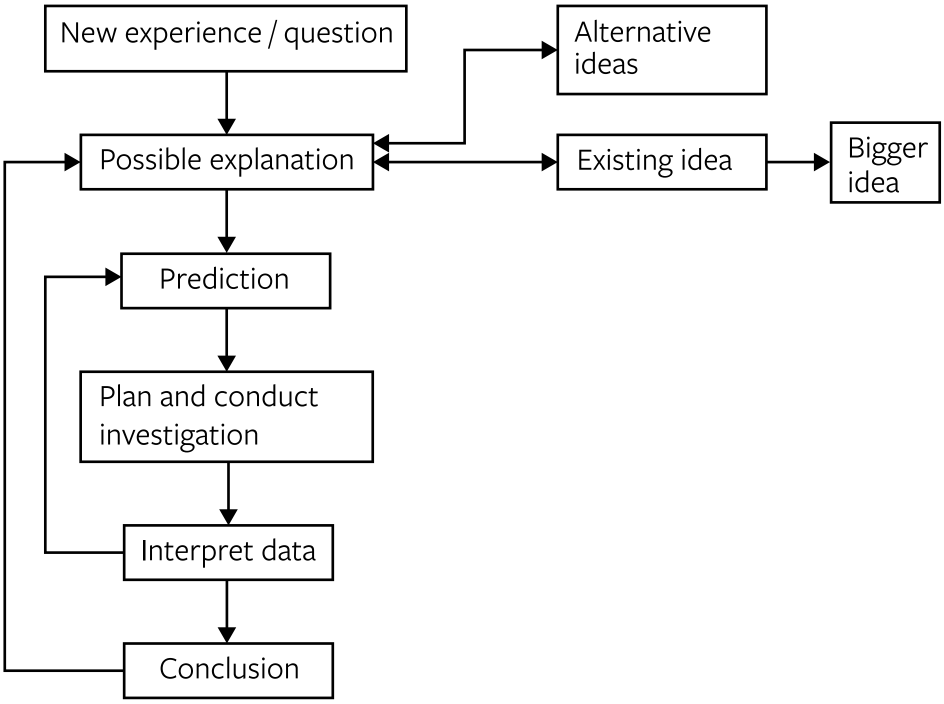

Figure 3: A model of learning through inquiry (based on Harlen, 2006)

This is the process of building understanding through collecting evidence to test possible explanations and the ideas behind them in a scientific manner, which we describe as learning through scientific inquiry.

3.2 Implications of the model

Modelling the building of understanding in this way offers a view of how smaller ideas (ones which apply to particular observations or experiences) are progressively developed into big ideas (ones that apply to a range of related objects or phenomena). In doing so, it is important to acknowledge, and to start from, the ideas the children already have, for if these are just put aside the children will still hold onto them because these are the ones that they worked out for themselves and make sense to them. They must be given opportunities to see for themselves which ideas are more consistent with evidence. Also, since ability to question, describe, propose, communicate and conclude through language is involved in this process, it follows that inquiry is closely tied to the development and use of appropriate language.

The model also draws attention to two important features of learning through inquiry: the need to introduce alternative ideas to the children's own and the role of inquiry skills.

3.2.1 Introducing alternative ideas

Consider an example of an inquiry by some 9 year olds. It began from their experience of moisture seen on the outside of a can of drink just taken from the 'fridge. The children's initial idea was that this was liquid from the drink leaking through the can. This was a possible explanation that they could test by seeing what happened when an empty can is put in the 'fridge. The result showed that the children's initial idea did not provide an explanation for which there was supporting evidence. They needed access to alternative ideas. In this context it would be possible to draw on children's other experiences of condensation to suggest an alternative idea to try. However, in other contexts, alternative ideas may be more difficult to introduce and some 'scaffolding' is required. 'Scaffolding' describes the introduction of ideas at a time and in a way that helps children to consider new ideas that they have not yet made 'their own' (Harlen & Qualter, 2014). The teacher provides support for trying an idea without urging it as the 'right answer', by suggesting, for example 'what if…?' of 'suppose that …?' 'what would we expect if… ?' The teacher need not be the only source of alternative ideas, which could come from the children, books, other adults, the internet, but in all cases it is the teacher's role to bring the ideas to the children in a way that allows them to try them out and see if they help in understanding the event more than their own ideas.

3.2.2 The role of inquiry skills

We can see that development of the children's idea is dependent on the inquiry skills that are used. If their observing, predicting, planning and conducting investigations, interpreting data, etc. is rigorous and systematic, in the way associated with scientific investigation, then ideas which do not fit the evidence will be rejected and those which do fit will be accepted and strengthened. But if this is not the case, then ideas that ought to be changed will be retained and children's 'everyday' ideas persist. This can happen when young children may not have developed skills to the appropriate degree or they may be unable, or unwilling, to use them. In such cases, when they make observations they may focus on those aspects that confirm and ignore those that challenge their ideas; they may 'predict' what they already know to be true; they may not control variables that ought to be kept unchanged.

Box 2: Implications for children

When learning through inquiry, over a period of time, children will be

- gathering evidence by observing real events or using other sources;
- pursuing questions which they have identified as their own even if introduced by the teacher, and raising further questions;
- making predictions based on what they think or find out;
- suggesting ways of testing their own or others' ideas to see if there is evidence to support these ideas;
- using and developing skills of gathering data directly by observations and measurement and by using secondary sources;
- working collaboratively with others, communicating their own ideas and considering others' ideas;
- assessing the validity and usefulness of different ideas in relation to evidence;
- reflecting self-critically about the processes and outcomes of their investigations.

Clearly the development of scientific inquiry skills is central to the construction of ideas that enable understanding. This is one important reason for giving attention to helping children to develop their inquiry skills and to become more conscious of using them with appropriate rigour. Another, of course, is that by reflecting on their learning they develop skills needed for making sense of new experiences in the future and for learning throughout life.

The condition 'over a period of time' in Box 2 is an important one, since not all aspects of learning through inquiry will be present in every activity, nor will all learning in science be through inquiry. There are some things that need to be known, such as conventions, names and the basic skills of using equipment, that are more efficiently learned by direct instruction as and when they are needed. Inquiry is required when understanding and the building of ideas is the aim and teacher should not be made to feel inadequate or guilty if all science lessons do not involve children in all the activities in Box 2.

On the other hand, teachers need to beware of pseudo-inquiry, where there is plenty of practical activity – observing, measuring and recording – but a lack of involvement of the children in making sense of phenomena or events in the natural world. This may be because the teacher is doing the interpretation for the children. It may also be that the content of the activities does not lead to the development of scientific models or explanations. This can happen when teachers who are perhaps unsure of their scientific understanding, tend to keep to rather trivial content (such as whether the colour of sweets affects their taste), regarding the sole aims of science inquiry as the use of a set of skills, disregarding the development of understanding.

Box 3: Implications for teachers

Teachers enable children to learn through inquiry when they

- provide opportunities for investigating materials, objects and phenomena at first hand or through using secondary sources;
- ask questions that require reasoning, explanations and reflection, and show interest in the children's answers;
- take action to help children to use and develop skills in collecting and interpreting relevant evidence;
- provide access to alternative procedures and ideas through discussion, reference to books, resources such as the Internet and other sources of help;
- set challenging tasks whilst providing support (scaffolding) so that children can experience operating at a more advanced level;
- encourage children through comment and questioning to check that their ideas are consistent with the evidence available;
- help children to record their observations and other information in ways that support systematic working and review, including the use of conventional representations and appropriate vocabulary;
- arrange for discussion of procedures and outcomes in small groups;
- encourage, through example, tolerance, mutual respect and objectivity in small group and whole class discussion;
- plan time for children to reflect on how they have learned and how this can be applied in future learning.

Box 3 summarises actions of teachers that are required to provide children with the opportunity to learn through inquiry. Behind these statements are implicit judgements that these are valuable actions leading to valued learning. Teachers are more likely to undertake these actions if they are convinced of the benefit of children having first-hand experience of investigating and observing phenomena, working collaboratively in groups, talking and arguing, and so on. The preparation that teachers need for this role, both in initial teacher education and professional development, has to do more than help teachers with the techniques of questioning, managing practical work, holding group and whole class discussions, etc. It should also convince teachers of the value of these techniques. For this the testimony of other teachers who work this way is important and so also is personal experience. Teachers and trainees need to have opportunity to experience for themselves the value of questioning, trying to answer questions through inquiry and reflecting on the process of learning this way.

4. Helping the development of science inquiry skills

Skills used in scientific investigation and inquiry are identified in slightly different ways in different curricula and standards statements. In the K-12 Framework recently produced by the National Research Council of the USA the word 'practices' is adopted instead of skills in order 'to emphasize that engaging in scientific investigation required not only skill but also knowledge that is specific to each practice.' (NRC, 2012, p. 30) However, elsewhere others, including the OECD continue to use the term skill, acknowledging that some knowledge is needed of what using it involves, there seems no reason to abandon the use of this familiar term here.

There are different types of inquiry (see Turner et al., 2011) which require greater emphasis on some skills than others. However there are four main groups of skills which ought to be represented in any activity that is described as 'science inquiry':

- **raising questions, predicting and planning investigations**
  (concerned with setting up investigations)
- **gathering evidence by observing and using information sources**
  (concerned with collecting data)
- **analysing, interpreting and explaining**
  (concerned with drawing conclusions)
- **communicating, arguing, reflecting and evaluating**
  (concerned with reporting, reflecting and applying).

We now consider for each group of skills some action that teachers can take and the types of questions that it is useful to ask to help children develop these skills. The emphasis on teachers' questions acknowledges the central role that these have in stimulating children's thinking and scientific investigation.

4.1 Helping development of questioning, predicting and planning skills

Box 4 sets out some key ways of helping children to develop these skills. In relation to questioning the aim is to help children to recognise the kinds of questions that lead to inquiries. Such questions need to be expressed in investigable form. One of the actions that teachers can take is to make time to discuss with children explicitly what this means and how to do it, using some examples. The AKSIS project (Goldsworthy et al., 2000) produced lists of questions for discussion with children in structured activities designed to increase awareness of the need to clarify questions. The idea is to help children realise that questions such as: 'Does toothpaste make a difference to your teeth?' 'Is margarine better for you than butter?' can only be answered when the meaning of 'making a difference' and 'better for you' have been clarified. There has to be some indication of the kind of evidence that could be collected to answer the question (even if, in some cases, the children might not be able to collect it themselves).

In relation to making predictions, children's predictions are often implicit and the link to an idea on which they are based is not recognised. Asking them to say not only what will happen, but why, helps them to make their predictions explicit and enables them to see the connection between an idea and the prediction from it that is tested.

Too often children's experience of what is required in planning an inquiry is by-passed because they are given written instructions to follow or their teacher guides their activities too strongly. In the early years, children's experience should include simple problems such that they can easily respond to 'How will you do this?' For example, 'How can you find out if the light from the torch will shine through this fabric, this piece of plastic, this jar of water, this coat sleeve?' Often young children will respond by showing rather than describing what to do. With greater experience and ability to 'think through actions' before doing them they can be encouraged to think ahead more and more, which is one of the values of planning.

If children are to develop the ability to plan there must be opportunities for them to start from a question and work out how to answer it. To take these steps by themselves is asking a great deal of young children and of older ones unused to devising inquiries. A set of questions related to the decisions they have to take provides a starting point. For instance, planning a fair test can scaffolded using a planning board on which children pin labels showing what they are going to change, what variables must stay the same and what has to be measured or observed to find the result.

Box 4: Developing skills of questioning, predicting and planning

Action that teachers can take

- Stimulate curiosity through classroom displays, posters, and inviting questions through a question board or box.
- Help children to refine their questions and put them into investigable form.
- Provide opportunities for planning by starting from a question to be answered by inquiry without giving instructions.
- Scaffold planning a fair test using a planning board.
- Talk through an inquiry that has been completed to identify how it could have been better planned.

Teachers' questions:

- 'what would you like to know about ...?'
- 'what do you think will happen if your idea is correct?'
- 'what do you think will happen if... or when...?'
- 'why do you think that will happen?'
- 'what will you need to do to find out...'
- 'how will you be make it 'fair'

4.2 Helping development of gathering evidence by observing and using information sources

Box 5 summarises some actions that teachers can take and the kinds of questions they can ask to encourage these skills. In the case of observing, the first essential is something to observe. As children will spend most time in the classroom it is important for this to be rich in opportunities for observation – displays of objects related to a theme, posters, photographs, living things, etc., with sources of further information nearby, should be regular features. Making time available is significant in encouraging observation, perhaps more than for other inquiry skills. Children need time to go back to things they may have observed only superficially or when a question has occurred to them about something they want to check.

Box 5: Developing skills of gathering evidence by observing and using information sources

Action that teachers can take

- Provide informal opportunities for using the senses for gathering information by: a) regular display of objects and phenomena for children to explore, with relevant information books or CD Roms accessible nearby; b) a collection of objects relating to a new topic two or three weeks ahead of starting it to create interest c) making time for observing
- Encourage observation through 'invitations to observe' - cards placed next to objects or equipment displayed, encouraging observation and attention to detail.
- Teach the correct use of instruments that a) extend the senses; b) can measure change or differences, such as sensors and probes.
- Teach the techniques for using information sources such as reference books and the internet/intranet.
- Set up situations where observations are shared.
- Organise visits to observe events and objects outside the classroom.

Teachers' questions:

- 'What do you notice that is the same about these...?'
- 'What differences do you notice between the ... of the same kind?'
- 'What differences do you see when you look through the lens?'
- 'How much longer, heavier,... is this than...?'
- 'What did you notice about the places where you found the most ...?'
- 'What more can you find out about...from the books and the internet?'

A display enables children to use odd moments as well as science activity time for observing and so increases an important commodity in the development of this skill.

Not all observations are made in the classroom, of course. On expeditions outside the classroom there is less opportunity to revisit objects and so it is essential for careful preparation outside if things are not to be missed. Observing is the basis of all means of collecting data in a practical situation. Where attention to detail or to small differences is necessary it will be appropriate to extend senses by using an instrument such as a hand lens or stethoscope and to use measuring instruments to quantify observations. Observation aids, such as the use of a hand lens can be taught through a card with a drawing placed next to some lenses and selected objects in the classroom display. Older children with the required manipulative skill can learn to use a microscope through similar informal opportunities. Other techniques, such as the use of sensors involving computers, need more formal instruction. Data can also be obtained from secondary sources, of course, from books, displays, film, television, computer-based sources and children will need to know how to use these sources properly.

4.3 Helping development of analysing, interpreting and explaining

Analysing and interpreting results means going further than collecting individual observations and recording them. It means trying to find patterns that relate various pieces of information to each other and to the ideas being tested. As with other inquiry skills, children need the opportunity and encouragement to do these things if they are to develop these competences. Linking results to the original question under investigation is a vital aspect of interpretation which can make all the difference in ensuring that inquiry leads to the development of understanding. The main thrust is to ensure that children use the results of their inquiries to advance their ideas. Asking 'How does this compare with what you expected/predicted?' brings the children back to the reason for their inquiry and to thinking about the ideas they were testing.

Explanations of phenomena can be given at different levels. We do not expect young children to 'explain' condensation of water on a cold can in terms of the energy of molecules but only in terms of what they observe about the conditions in which it takes place. The aim is to help children reach explanations that are consistent with the evidence available to them at a particular time.

Some of ways teachers can help are summarised in Box 6.

Box 6: Developing skills of analysing, interpreting and explaining

Action that teachers can take

- Plan the topic or lesson to make sure that the thinking does not stop when data have been collected or observations made and recorded.
- Provide time and opportunities for children to identify simple patterns or relationships which bring their results together.
- Ensure that results are used to decide whether a prediction was confirmed or whether a question was answered.
- Talk about what has been learned about the phenomenon investigated not just the observed effects.
- Encourage identification of overall statements (conclusions) that bring all observations together.

Teachers' questions:

- 'How did what you found compare with what you expected?'
- 'Did you find any connection between … and …?'
- 'What did you find makes a difference to how fast… how far… how many…?'
- 'What do you think is the reason for …?'

4.4 Helping development of skills of communicating, arguing, and evaluating

Communication among children plays an important part in their learning. Some actions that teachers can take to encourage communication and reflection are summarised in Box 7. Thinking and speaking are connected; finding ways of communicating thoughts to others helps to clarify for ourselves what we mean. So regular class discussion of what children have found in group activities is important for development of understanding and for recognising how the skills of collecting and interpreting information were used in arriving at this understanding. Such exchanges are particularly useful if they are conducted so that children question each other, ask for explanations as well as descriptions and suggest improvements in what was done.

Box 7: Developing skills of communicating, arguing, reflecting and evaluating

Action that teachers can take

- Provide opportunities for oral reporting and time for preparing so that procedures and ideas are shared.
- Provide children with a personal note-book for recording and reflection.
- Discuss with children how they might use their notebook and set aside time for them to use it.
- Provide ideas about how to record certain kinds of information, using tables, drawings with labels and symbols.
- Discuss ways of communicating particular information to particular audiences.
- Discuss criteria for evaluating reports and provide time for self-assessment.
- Give time to review activities and reflect on whether questions could have been better expressed, other variables controlled, measurements repeated, etc.

Teachers' questions:

- 'How are you going to keep a record of what you do and find?'
- 'What kind of chart/ graph/ drawing do you think is the best way to show the results?'
- 'How can you explain to the others what you did and what happened?'
- 'How can you show that (what evidence do you have that) your conclusion is right?'
- 'What other conclusions can you draw from your results?'
- 'If you did this again, what would you change to make it better?'

As noted earlier in section 2.1, arguing does not mean contesting views and opinions as in everyday arguments. Rather it is the process of supporting claims and conclusions with evidence. Sometimes children assert what they would like to happen rather than what does happen, particularly if the latter challenges their preconceived ideas or beliefs. They need to realise and ensure that what they report and claim in science in based on evidence.

The actions teacher can take, suggested by Osborne et al. (2004) include modelling behaviour of expecting children to give a justification for their views, encouraging children to challenge each other ('how do you know that?') and to expect counter arguments.

The same arguments apply to writing as to talking, but children need more help to develop the skills of using personal writing to support their thinking. Providing children with a personal notebook is a start. However, they also need to recognise its function not just as an aid to memory, but also as a means of organising their thinking, through writing rough notes and recording observations.

5. Conclusion

Scanning across the suggestions for helping development of these groups of skills reveals some common themes. Frequent mention has been made of certain points which appear to be key strategies that can be applied to all inquiry skills:

- Providing opportunity to use inquiry skills in the exploration of materials and phenomena at first-hand.
- Asking question that require the use of the skills (and allowing time for thinking and answering).
- Providing opportunity for discussion in small groups and as a whole class.
- Encouraging critical review of how activities have been carried out.
- Providing access to the techniques needed for advancing skills.
- Involving children in communicating in various forms and reflecting on their thinking.

These are key actions that are central to pedagogy that supports learning through inquiry. The development of inquiry skills not only will enable children to build their understanding of the world around but also to understand the nature of science, scientific inquiry and reasoning, develop positive attitudes both within and towards science and appreciation of the contribution of science to society and of how science is used in technology and engineering.
If these goals seem rather distance from young children, we must recall that we are talking about development and this starts from simple foundations set down from the early years of education. Without this start later experiences will lack the foundation for building competences and understanding needed for later learning and throughout life.

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